Mitigating Oscillations

EPRI Update

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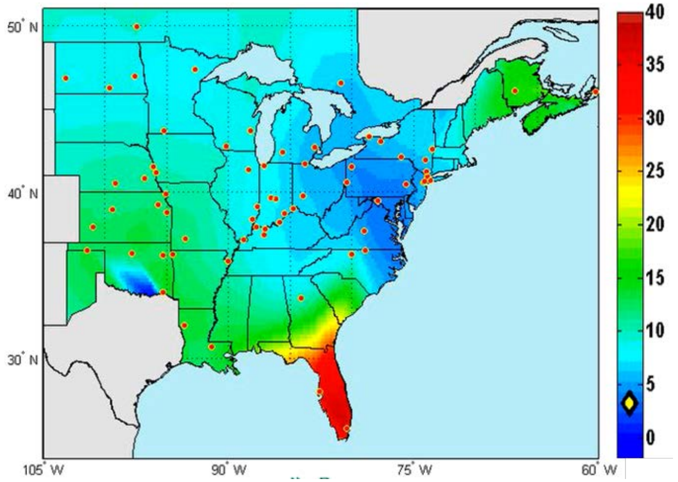
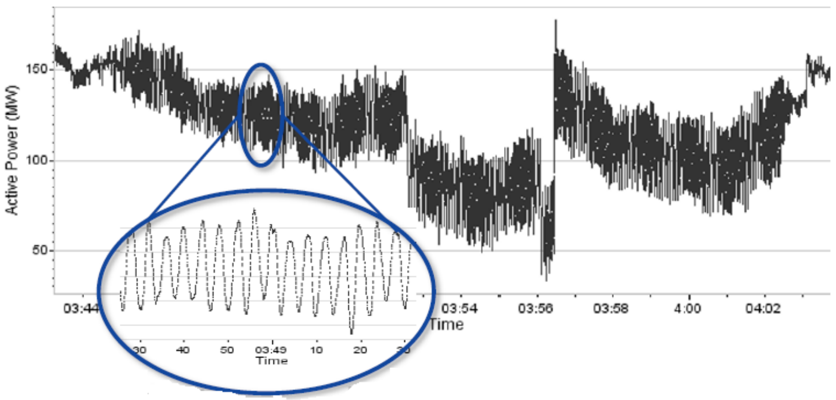
Low Frequency Oscillations

Unites States

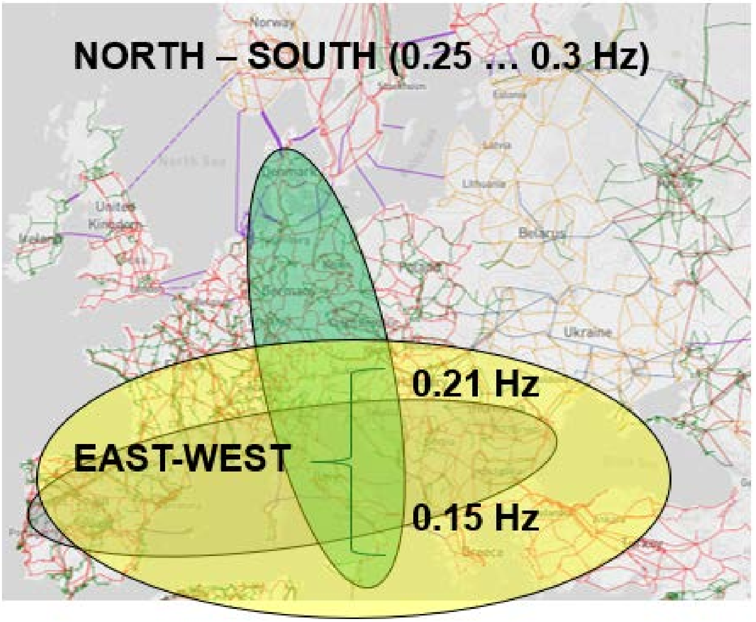
- January 2019 event
  - 0.25 Hz oscillations propagated through entire Eastern Interconnection
  - Lasted for 17 mins
  - Source: Florida generator





Continental EU System

- 3 EU Events
  - Dec 3rd 2017 (0.29 Hz)
  - Dec 1st 2016
  - February 19th & 24th 2011

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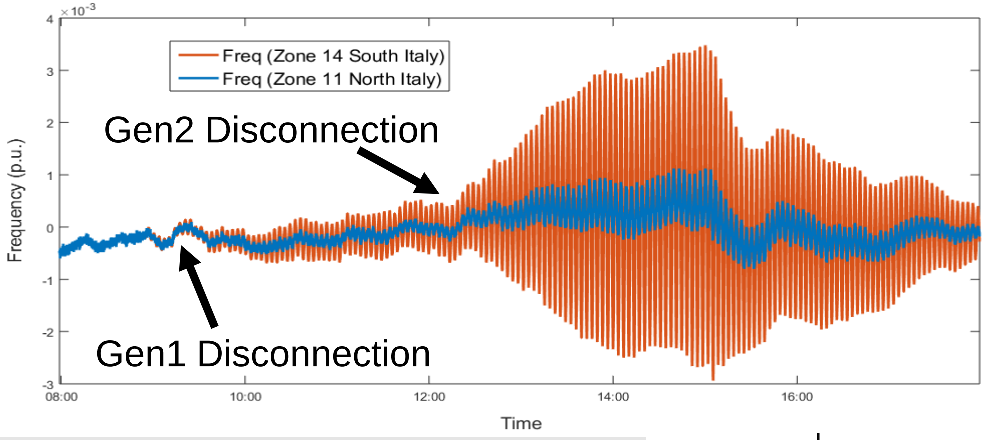
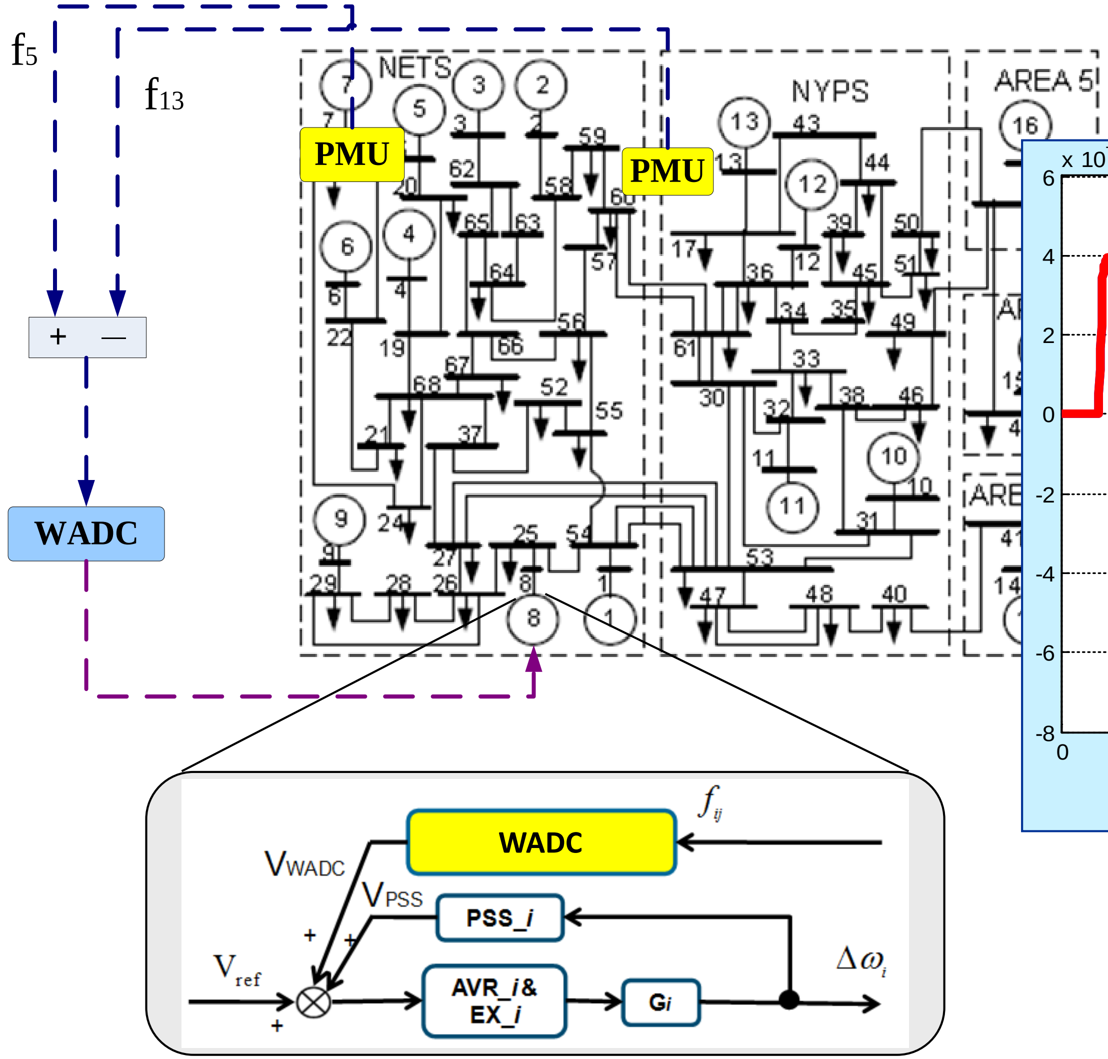
Oscillation Event 03.12.2017

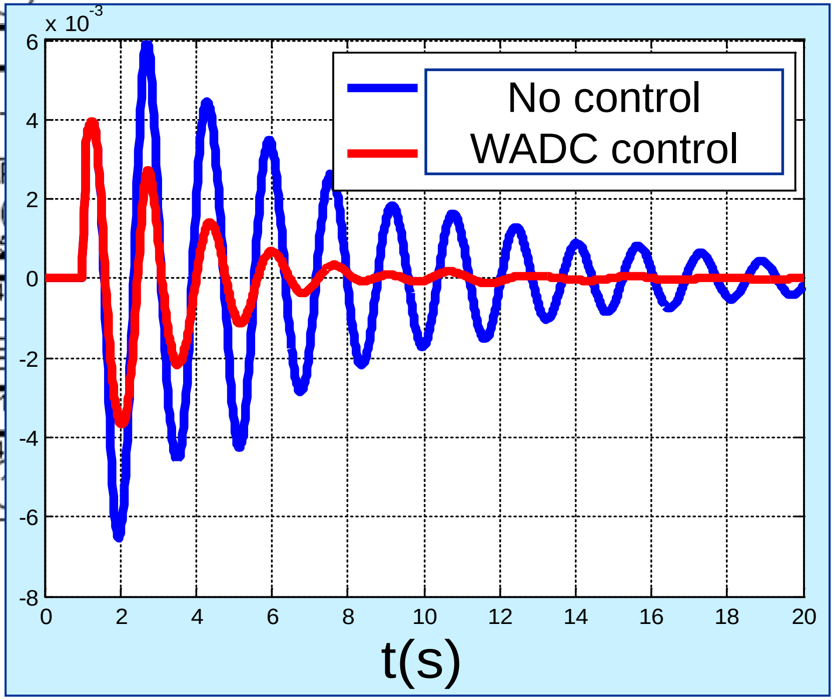
System Protection and Dynamics WG

March 2018



Synchrophasor-Based Wide Area Oscillations Damping Controller



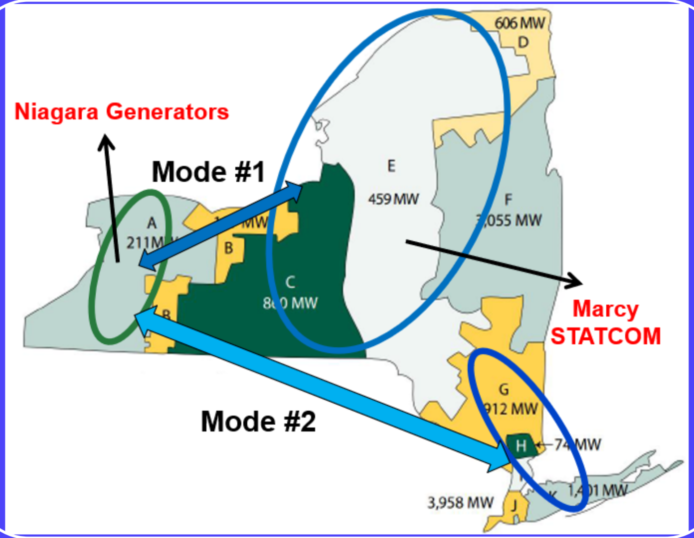


In collaboration with University Tennessee Knoxville (UTK)

- **Improved Damping of Target Inter-area/Intra-area Oscillations Mode**
- **Application of Synchrophasor Technology in Closed Loop Wide Area Control**

WADC Case Studies

NYPA Case Study

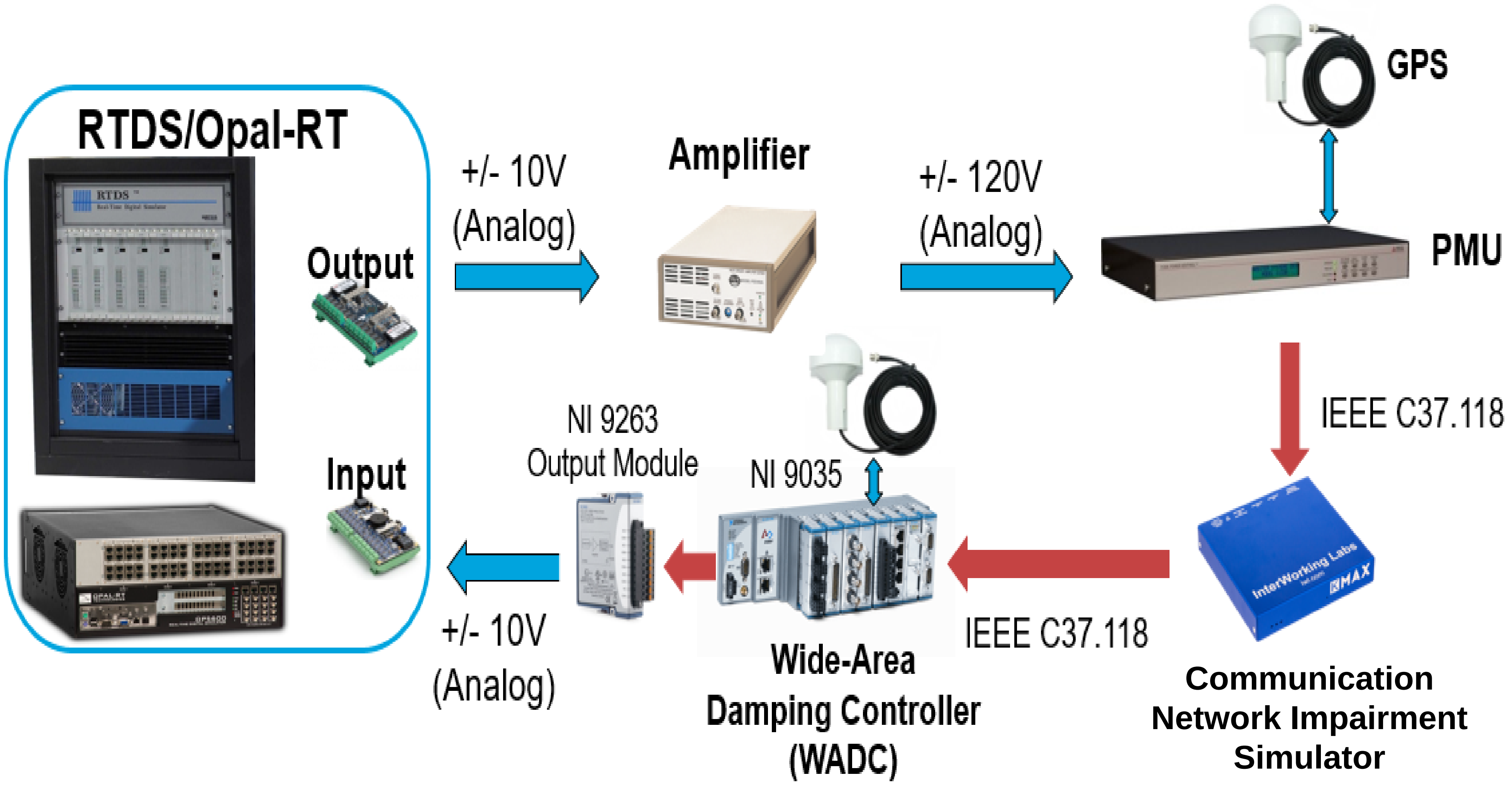


- Study using planning models
- Two dominant modes
  - 'West-North' mode
  - 'West-South' mode
- Actuators: Marcy STATCOM and Niagara generators

TERNA Case Study

- 2017 event replicated in simulations
- WADC design
  - Actuators: 2 synchronous condensers in South Italy
  - Input: South-North frequency difference

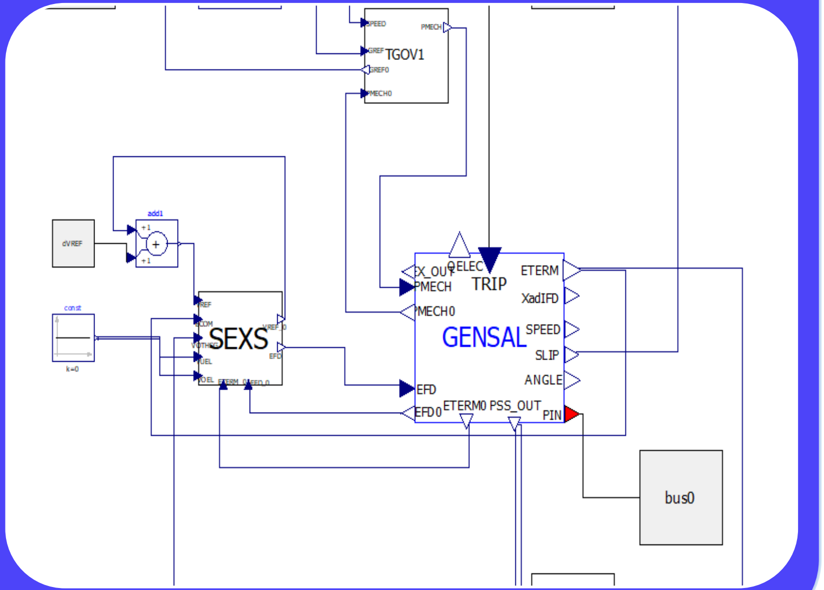
WADC Hardware-In-the-Loop Implementation



Investigate Controller Performance Under Realistic Operating Conditions

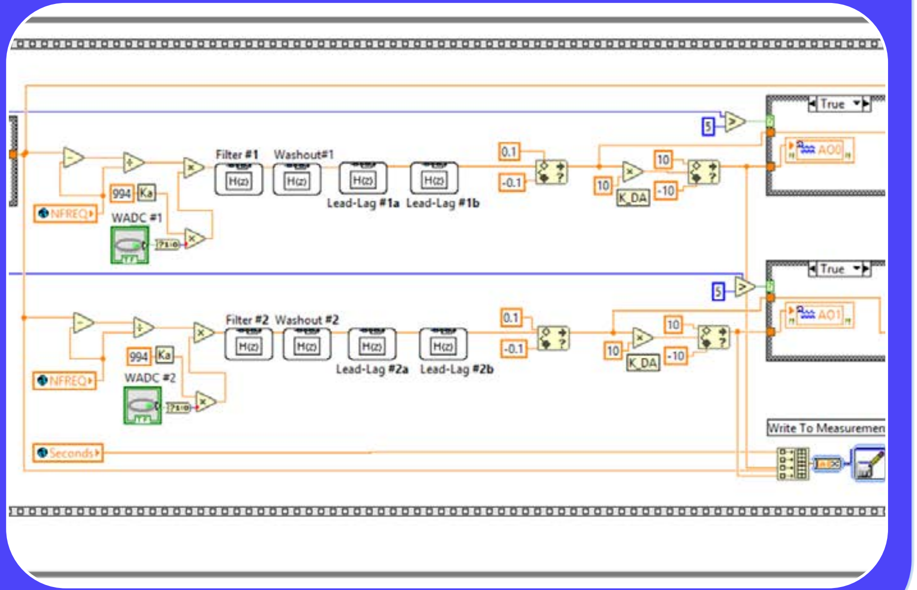
WADC Hardware-In-the-Loop Setup

Model Implementation



- Grid Model in Digital Simulator Format
  - RTDS RSCAD
  - OPAL-RT ePHASORSIM
- Comparison with Offline Simulations

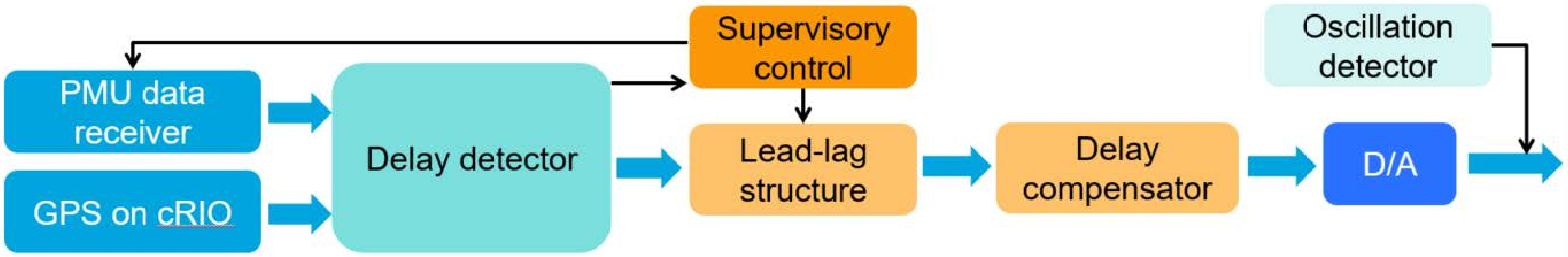
Controller Implementation



- Hardware: National Instrument's CompactRIO
- PMU Data Receiver: IEEE C37.118
- WADC Structure
- D/A Converter
- Visualization GUI

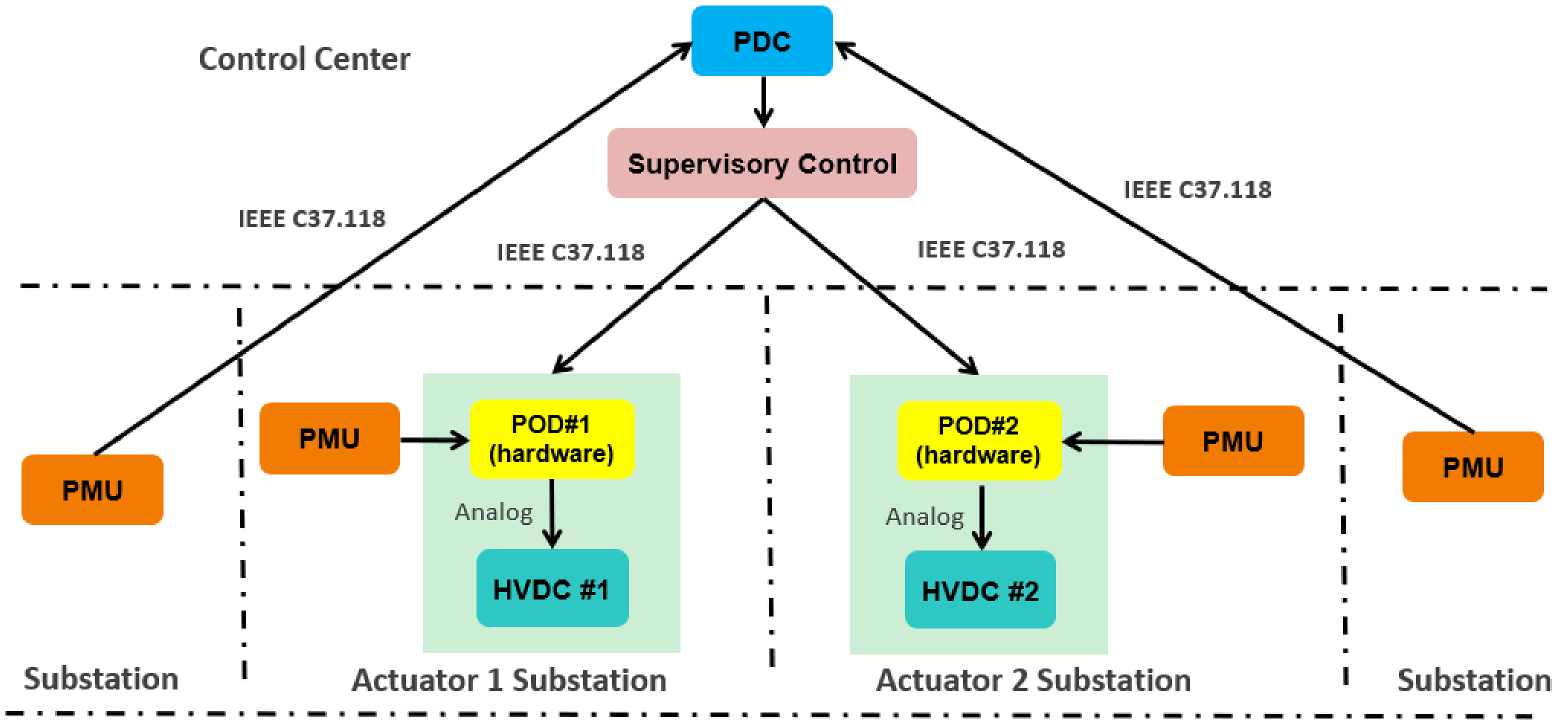
Hardware Implementation of WADC

		Block name	Function
Basic modules	1	PMU data receiver	Unpack PMU data package complying with C37.118
	2	Lead-lag structure	Basic control function
	3	D/A conversion	Convert digital signal to analog signal
Advanced modules	4	GPS module	Capture absolute timestamp
	5	Delay detector	Estimate the time delay
	6	Delay compensator	Eliminate impact of time delay
	7	Supervisory control	Switch PMU channel, enable/disable controller
	8	Oscillation detector	Disable controller if no oscillation



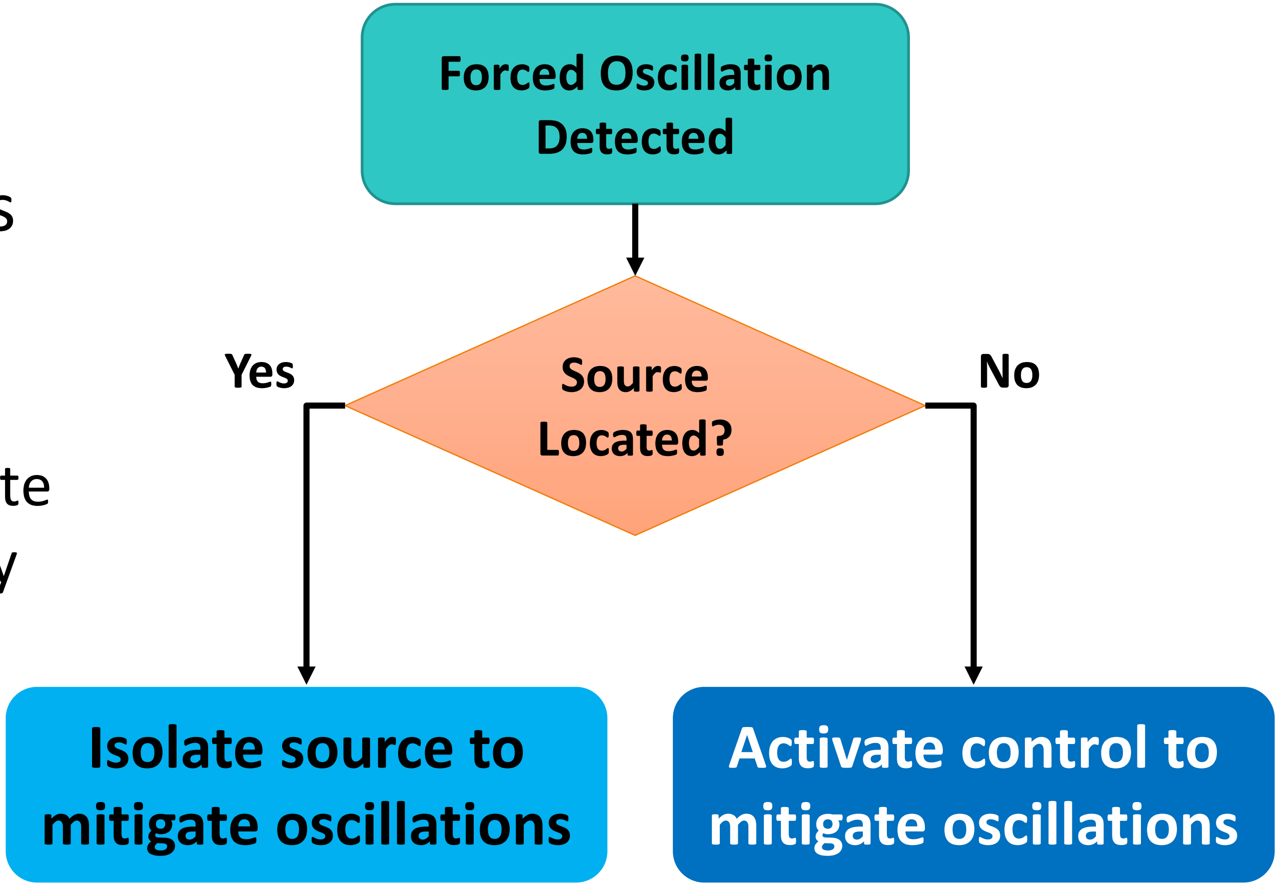
WADC with Backup PMU Channels and Backup Actuators

- Distributed control structure with multiple PMUs and multiple actuators
  - Multiple actuators in case of actuator out-of-service
  - Supervisory control:
    - Central: Select actuators
    - Local: Switch to local PMU in case of loss of remote PMUs



Forced Oscillations Mitigation

- Forced Oscillation Source Location
- Use of Battery Energy Storage Systems (BESS) and/or IBRs to suppress magnitude of forced oscillations
  - If source cannot be located quickly, activate control to reduce forced oscillation energy
  - Allow sufficient time to locate source



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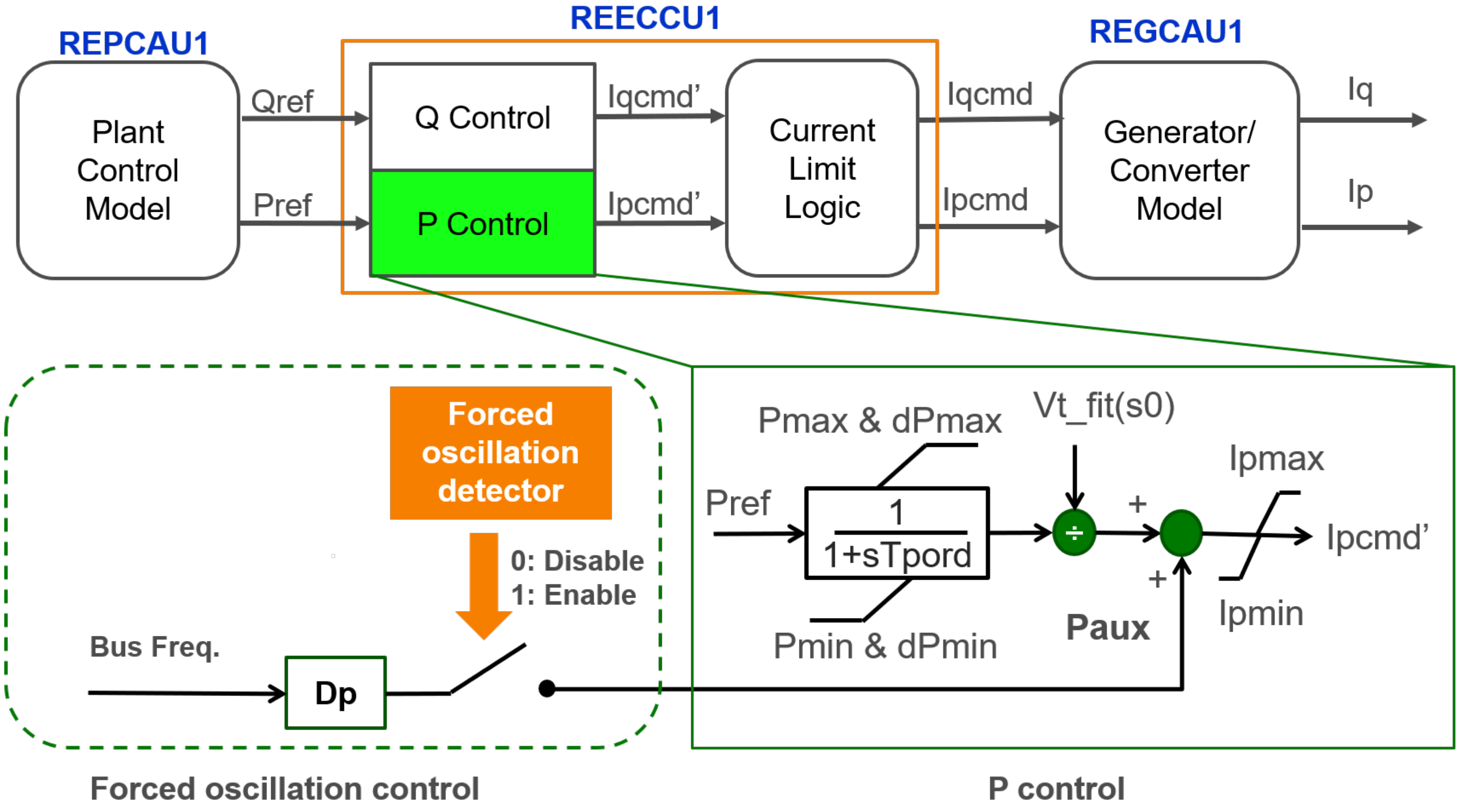
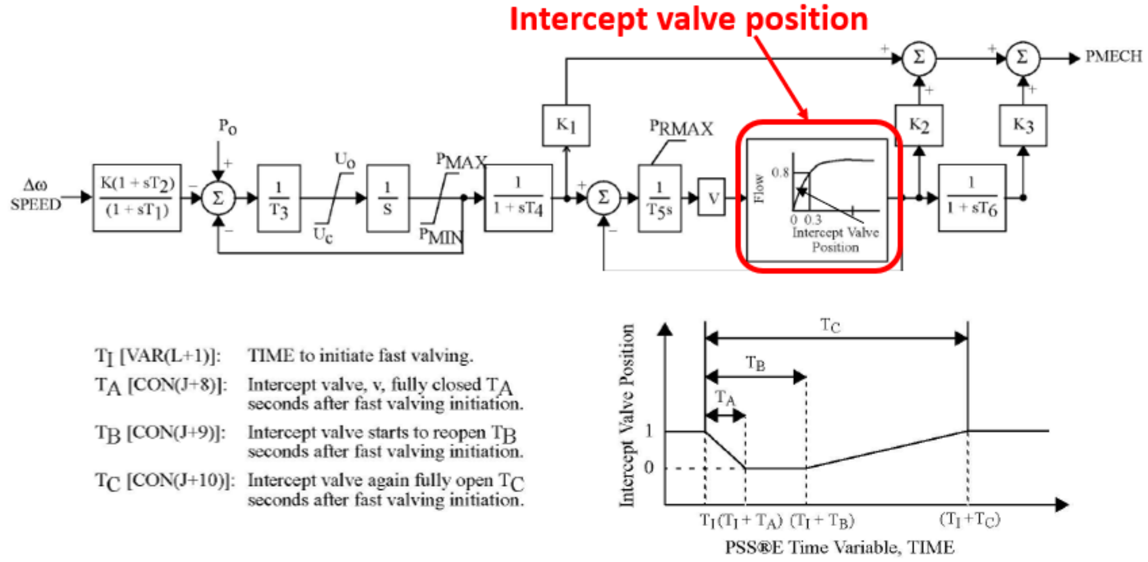
Forced Oscillation Mitigation Using BESS

- Controller
  - Input: Frequency deviation of a HV bus close to the BESS
  - Output: Added to $Paux$ to modulate the active current command
  - Forced oscillation detector
  - Droop control
- WECC BESS model used
  - Active power control of the BESS electrical control model

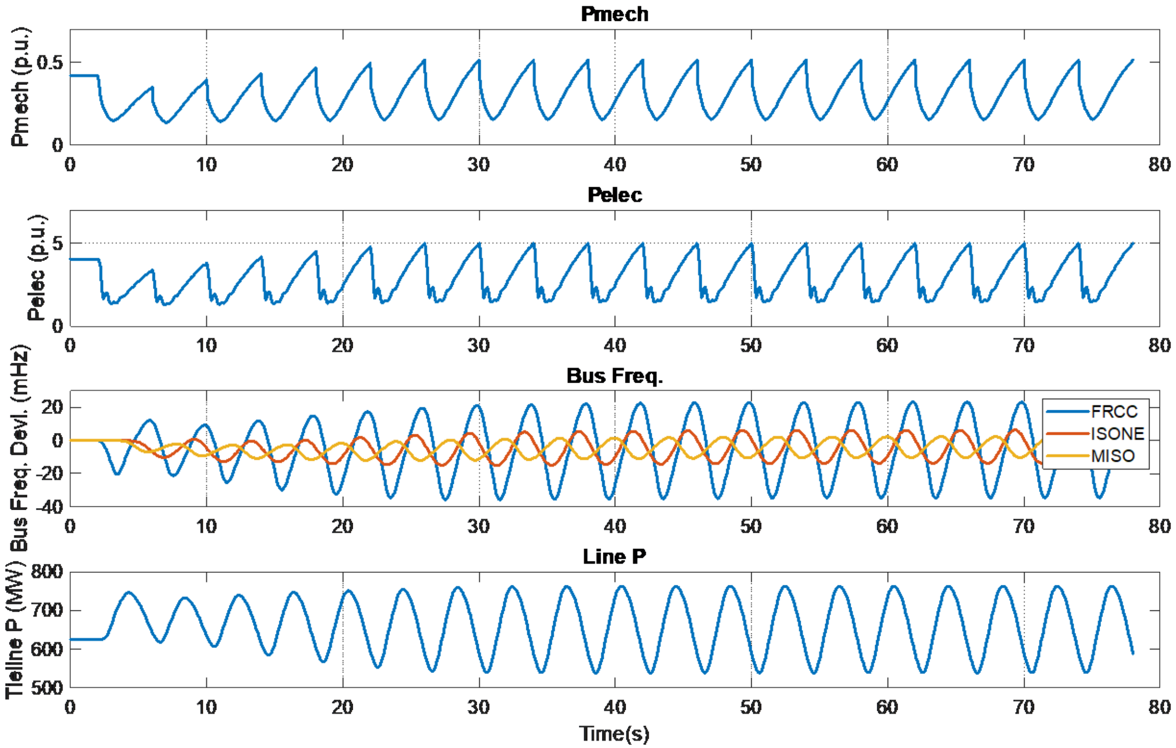


Replication of EI January 2019 Forced Oscillation Event

- Fast valving feature of the TGOV3 model used to replicate the event
- Initiate fast valve every 4 seconds

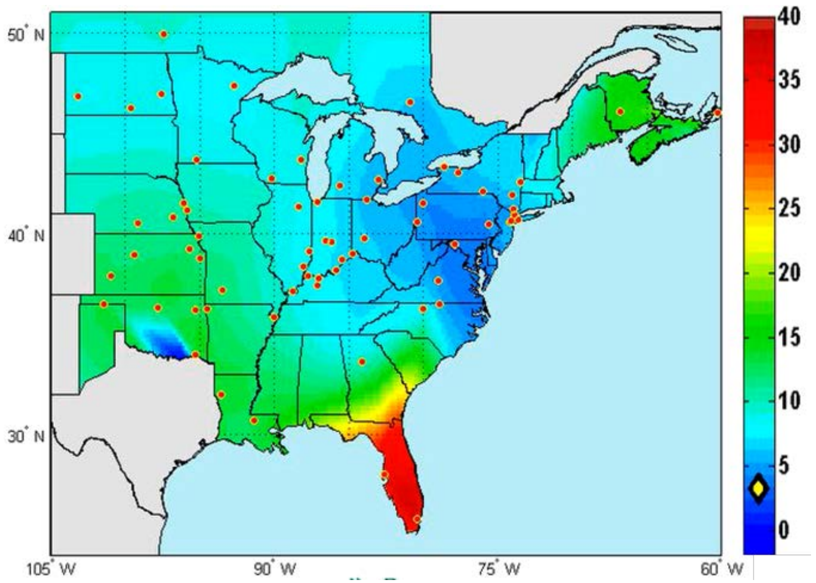


TGOV3 governor model

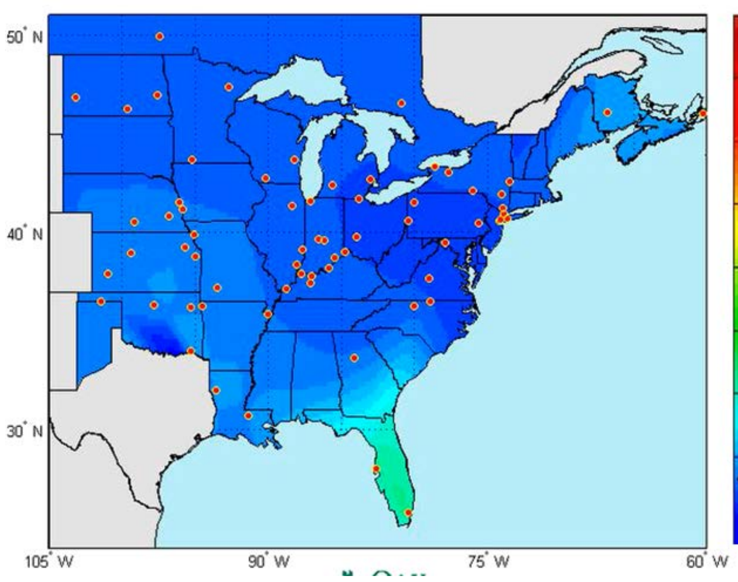


Simulation Results

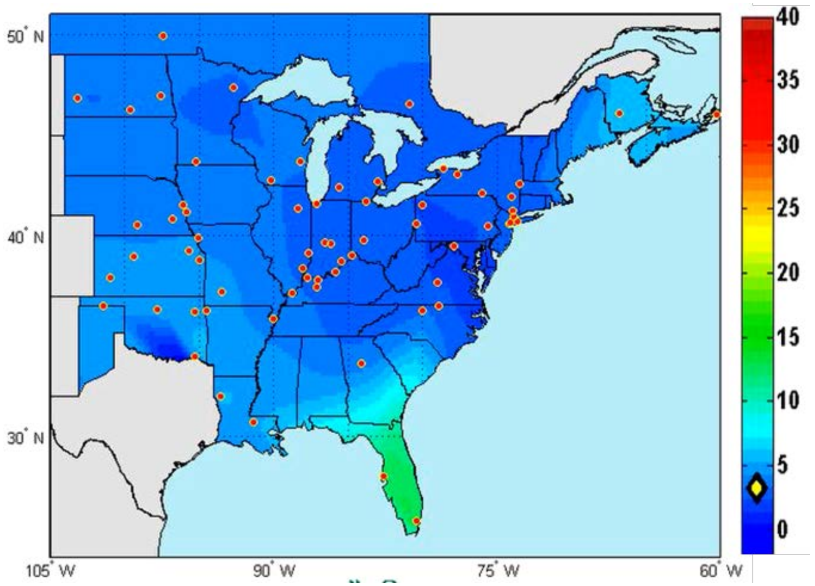
- Source location: Florida
- BESS location: Florida



No Control



With Control (1×409MW BESS in Florida)



With Control (12×35MW BESSs in Florida)

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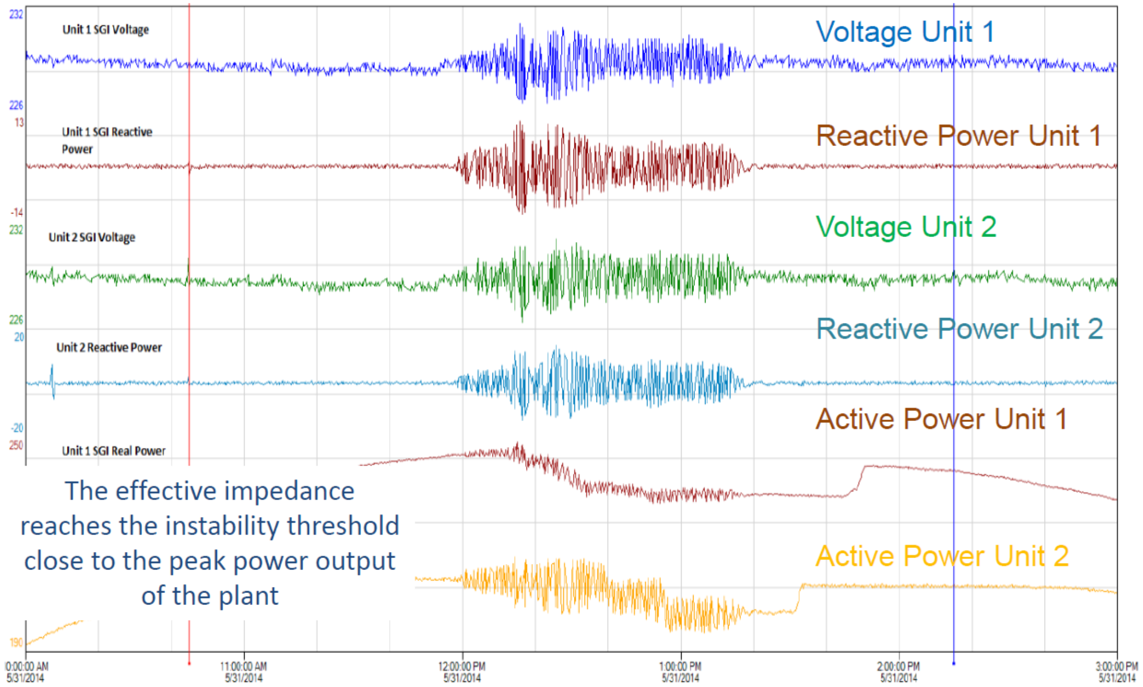
Sub-Synchronous Oscillations due to Inverter Controls

- Inverter controls might create sub-synchronous oscillations due to control interactions and/or network resonance
- Such oscillations are usually in the frequency band of 5.0-15.0 Hz

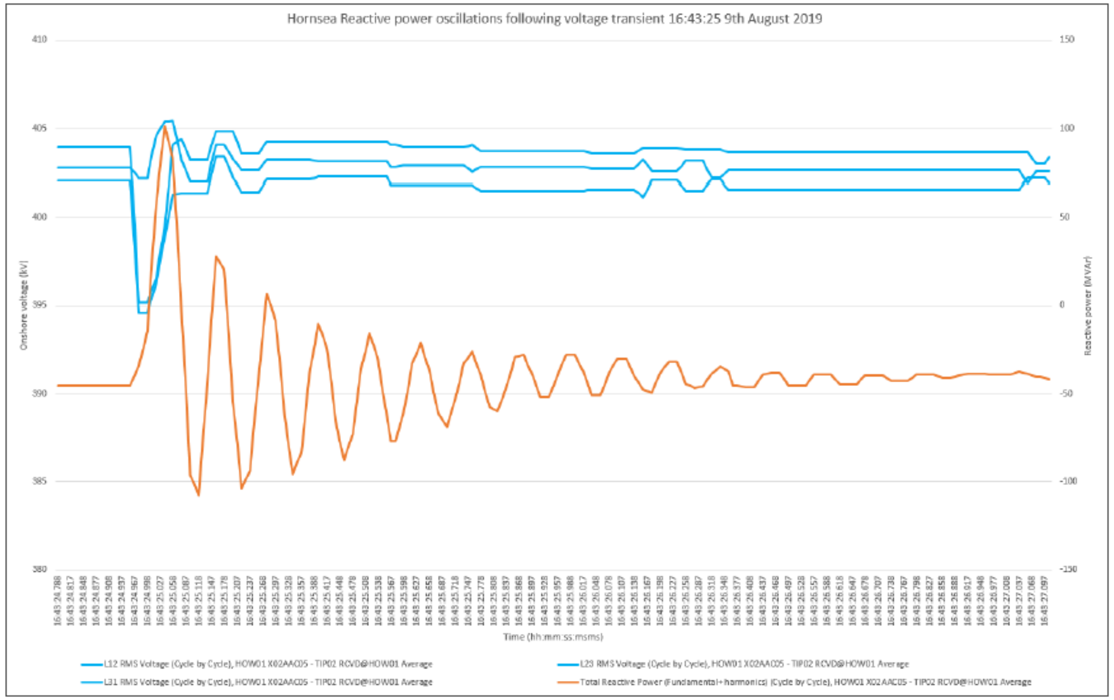
California

PV Plant – ~7 Hz Oscillation



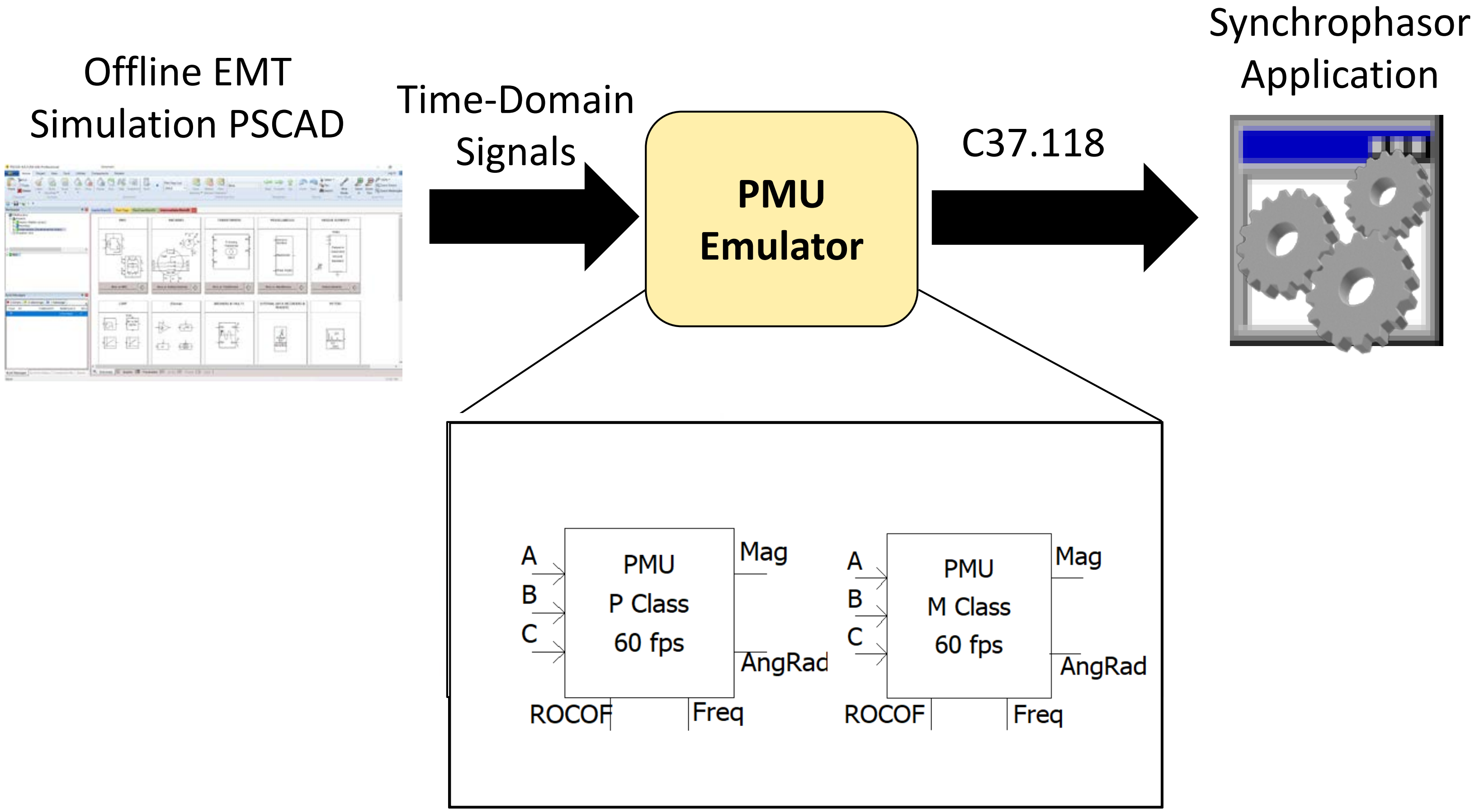
GB August 2019 Event

~ 8Hz oscillations observed at Hornsea wind park reactive power after a 2% voltage step change



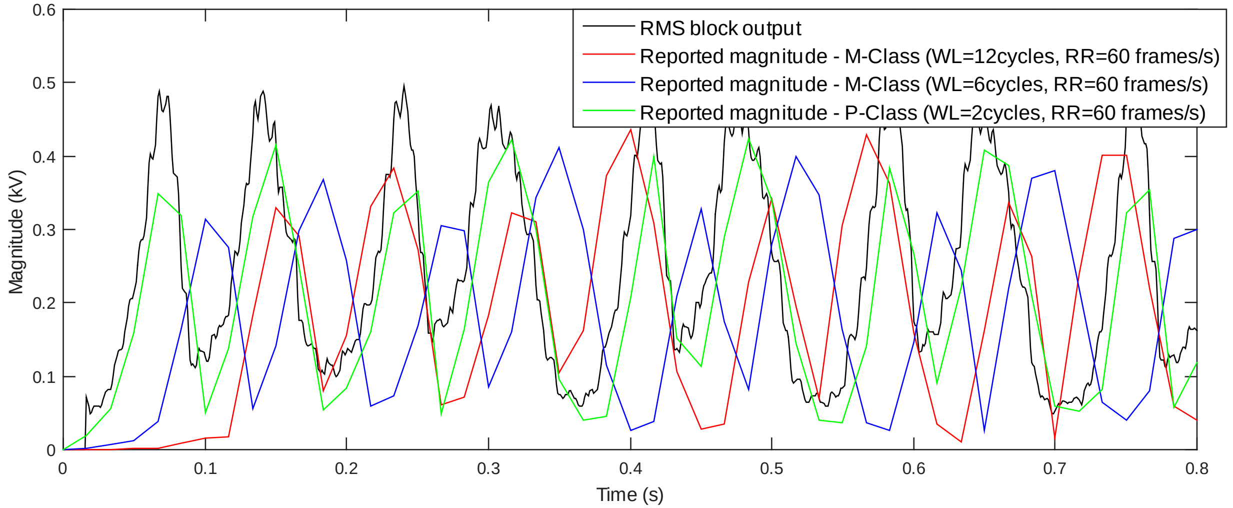
PMU Emulator, A Tool to Investigate Impact of PMU Signal Processing

- PMU Emulator provides “simulated Synchrophasors” by applying PMU signal processing model to phasors and time-domain signals from dynamic and EMT simulation tools

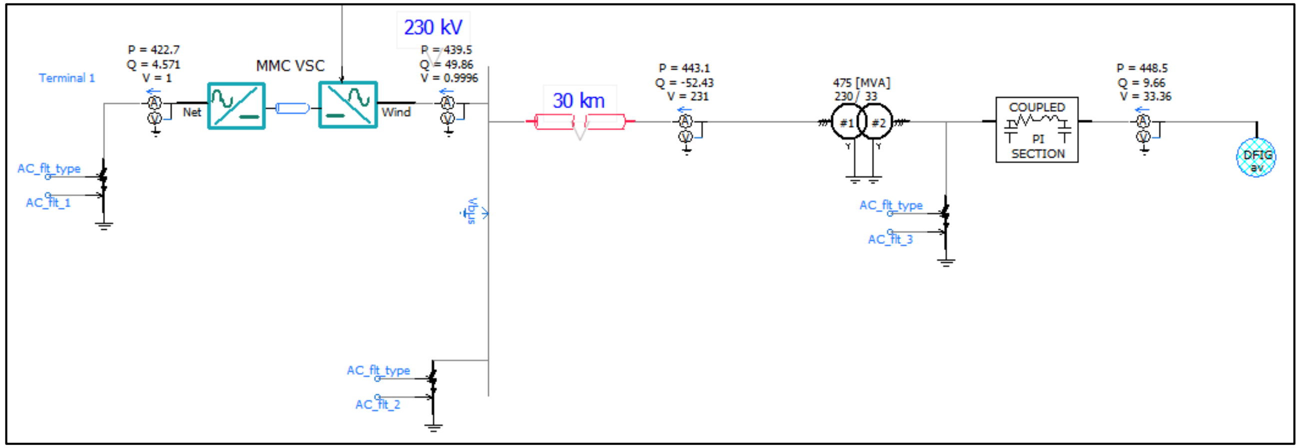


PMU Limitations in Monitoring Fast Dynamics in Low Inertia Systems

- Signal processing within a PMU might compromise the accuracy of the monitored oscillations



PMU reported magnitude (RR=60 frames/s) versus true RMS of input signal



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